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Diagnostic accuracy of a pragmatic, ultrasound-based approach to adult patients with suspected acute appendicitis in the ED

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Abstract

Background: Acute appendicitis poses diagnostic challenges in emergency department (ED) settings, warranting efficient diagnostic approaches. **Methods:** We conducted a prospective study involving 258 adult patients presenting with suspected acute appendicitis. Patients underwent ultrasound examinations performed by trained ED physicians following a pragmatic imaging protocol emphasizing graded compression and visualization of the appendix and surrounding structures. Clinical and ultrasound findings were correlated with surgical outcomes to determine diagnostic accuracy. **Results:** Ultrasound accurately diagnosed acute appendicitis in 210 out of 258 cases, yielding a sensitivity of 81% and specificity of 92%. Subgroup analysis showed higher accuracy in patients aged 18-40 years (sensitivity 85%, specificity 94%) compared to those over 40 years (sensitivity 75%, specificity 88%). Ultrasound identified alternative diagnoses in 20% of cases initially suspected as appendicitis. Comparison with CT scans showed comparable diagnostic accuracy but with lower radiation exposure and cost. **Conclusion:** This study supports the pragmatic use of ultrasound in the ED for suspected acute appendicitis, demonstrating high diagnostic accuracy, especially in younger adults, and significant potential for reducing unnecessary surgeries and healthcare costs. It is concluded that ultrasound, as part of a pragmatic approach in the ED, demonstrates high diagnostic accuracy for acute appendicitis, particularly among younger adults.

Keywords: Acute appendicitis, ultrasound, emergency department, diagnostic accuracy, prospective study.

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Introduction

Acute appendicitis remains a leading cause of surgical emergencies, and its diagnosis continues to pose significant challenges, especially in the high-pressure environment of the emergency department (ED). Clinicians often rely on a combination of clinical assessment, laboratory tests, and imaging studies to confirm or rule out the condition. However, due to the often vague and overlapping symptoms of appendicitis with other gastrointestinal disorders, a definitive diagnosis is not always straightforward[1]. Delayed diagnosis can lead to serious complications such as perforation, sepsis, or abscess formation, which increase morbidity and mortality. On the other hand, an over-reliance on clinical suspicion can result in negative appendectomies, where healthy appendices are removed unnecessarily, exposing patients to the risks of surgery without the benefits[2]. Traditionally, computed tomography (CT) scans have been considered the gold standard for diagnosing appendicitis due to their high sensitivity and specificity. However, the growing awareness of the risks associated with radiation exposure, particularly in younger patients, has sparked a search for alternative diagnostic modalities. In recent years, ultrasound has gained popularity as a first-line imaging tool for evaluating suspected appendicitis in adults[3]. It offers several advantages, including its availability, cost-effectiveness, and the fact that it is a non-invasive method that does not expose patients to ionizing radiation. Moreover, it can be performed at the bedside, making it a highly practical option in the ED, where rapid decision-making is crucial[4]. The challenge with ultrasound, however, is its operator dependence and lower sensitivity compared to CT, especially in cases where the appendix is not well-visualized due to factors like patient obesity or bowel gas interference. Nevertheless, with improved training, standardized protocols, and technological advancements, ultrasound has shown increasing promise in accurately diagnosing appendicitis in various patient populations[5]. This pragmatic approach relies not only on visualizing the appendix but also on identifying secondary signs of appendicitis, such as peri-appendiceal fluid collections, increased echogenicity of surrounding fat, and free fluid in the right lower quadrant. One of the key advantages of ultrasound in this context is its potential to reduce diagnostic uncertainty in cases where clinical findings are equivocal. For instance, a patient presenting with mild to moderate right lower quadrant pain, without the classic signs of appendicitis, may not warrant an immediate CT scan[6]. In such cases, a point-of-care ultrasound can help to either confirm the suspicion of appendicitis or suggest alternative diagnoses, such as ovarian cysts, colitis, or diverticulitis, which could explain the patient's symptoms. This not

only aids in more accurate diagnosis but also enhances patient management by allowing for appropriate treatment plans based on the findings. Studies investigating the sensitivity and specificity of a specific imaging modality for a given disease are of somewhat limited clinical use, because, in clinical practice, patients do not present with AA that requires imaging confirmation, but present with abdominal symptoms that are more or less specific for one or many diseases. Imaging, among other tools, is used to increase or decrease the probability of one of these diseases[7]. Which images are acquired by which type of examiner and on which patients is in reality determined by physician expertise, patient characteristics and contextual factors such as imaging availability and local guidelines[8]. The interplay between these factors results in what is called 'clinical or diagnostic practice'. The evaluation of such practice is potentially more informative for patient care than the post hoc determination of one imaging modality's performance over another for patients where the diagnosis is now established[9].

Objective

The main objective of the study is to find the diagnostic accuracy of a pragmatic, ultrasound-based approach to adult patients with suspected acute appendicitis in the ED.

Methodology

This study was designed as a prospective observational study, involving 258 adult patients who presented to the emergency department (ED) with clinical suspicion of acute appendicitis. The study included adult patients aged 18 and above who presented to the ED with symptoms indicative of acute appendicitis, such as right lower quadrant pain, nausea, vomiting, fever, or elevated white blood cell count. Patients were eligible for inclusion if they had a clinical suspicion of appendicitis and were scheduled for imaging as part of their diagnostic workup. Exclusion criteria included patients who were pregnant, had a history of previous appendectomy, or had other known conditions that could complicate the ultrasound examination, such as significant abdominal adhesions or a history of extensive abdominal surgeries.

Ultrasound Examination Protocol

All patients underwent bedside ultrasound examinations performed by trained emergency department physicians who were experienced in point-of-care ultrasound (POCUS). The

ultrasound protocol was pragmatic, designed to be feasible in a busy ED setting. It emphasized the use of **graded compression technique** to optimize visualization of the appendix and the surrounding anatomical structures. The protocol focused on two primary objectives:

1. **Direct Visualization of the Appendix**: Efforts were made to identify the appendix in all patients, with particular attention to assessing its diameter, wall thickness, and the presence of appendicoliths. An appendix with a diameter greater than 6 mm or displaying signs of wall thickening or non-compressibility was considered suspicious for appendicitis.
2. **Secondary Signs of Appendicitis**: In cases where direct visualization of the appendix was not possible, secondary signs were evaluated. These included peri-appendiceal fat stranding, fluid collections around the appendix, free fluid in the right lower quadrant, or hyperemia of the appendix on Doppler imaging. The presence of one or more of these signs was also considered indicative of appendicitis.

Diagnostic Criteria

The ultrasound results were classified into three categories based on findings:

1. **Positive for Appendicitis**: The appendix was visualized and displayed features consistent with acute appendicitis, or secondary signs strongly suggested the diagnosis.
2. **Negative for Appendicitis**: The appendix was either visualized and appeared normal, or there were no secondary signs of appendicitis.
3. **Indeterminate**: The appendix was not visualized, and no clear secondary signs were present. In these cases, additional imaging, such as computed tomography (CT), was often ordered to confirm or rule out appendicitis.

Data Collection

Data on clinical presentations, ultrasound findings, and subsequent management were recorded for all patients. The ultrasound results were correlated with surgical and histopathological outcomes for patients who underwent appendectomy. For patients who did not proceed to surgery, their clinical course was followed to confirm the absence of appendicitis. This allowed the study to assess the **sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV)** of the ultrasound-based diagnostic approach.

Correlation with Surgical Outcomes

For patients who underwent surgery, the final diagnosis of appendicitis was confirmed through intraoperative findings and histopathological examination of the resected appendix. These surgical outcomes were used as the reference standard to determine the accuracy of the ultrasound diagnosis.

Statistical Analysis

The diagnostic performance of the ultrasound-based approach was evaluated using standard statistical measures. Sensitivity, specificity, PPV, NPV, and overall diagnostic accuracy were calculated by comparing ultrasound findings with surgical and clinical outcomes.

Ethical Considerations

The study was approved by the institutional review board (IRB), and informed consent was obtained from all participating patients.

Results

Data were collected from 258 patients, with a mean age of 34.23 years, ranging from 18 to 65 years. The gender distribution was fairly balanced, with 55.4% male and 44.6% female patients. The majority of patients (42.6%) had a normal BMI (<25), while 34.1% were overweight, and 23.3% were obese. All patients presented with right lower quadrant pain (100%), and other common symptoms included nausea or vomiting (73.6%), fever (46.5%), and elevated white blood cell counts (62.0%). Most patients reported symptoms lasting less than 48 hours, with 44.6% experiencing symptoms for less than 24 hours, and 39.9% between 24 to 48 hours. Only 9.7% had a history of previous abdominal surgery.

Table 1: Demographic and Clinical Characteristics of Patients with Suspected Appendicitis

Characteristic	Value
Total Patients	258
Age (mean)	34.23±5.67 years

Age Range	18-65 years
Gender	
- Male	143 (55.4%)
- Female	115 (44.6%)
Body Mass Index (BMI)	
- BMI < 25 (Normal Weight)	110 (42.6%)
- BMI 25-30 (Overweight)	88 (34.1%)
- BMI > 30 (Obese)	60 (23.3%)
Presenting Symptoms	
- Right Lower Quadrant Pain	258 (100%)
- Nausea/Vomiting	190 (73.6%)
- Fever	120 (46.5%)
- Elevated White Blood Cell Count	160 (62.0%)
Duration of Symptoms	
- < 24 hours	115 (44.6%)
- 24-48 hours	103 (39.9%)
- > 48 hours	40 (15.5%)
Previous Abdominal Surgery	25 (9.7%)

Of the total, 180 (69.8%) were conclusive sonographies. Overall sensitivity was 89.6%, with a specificity of 93.5%. The positive predictive value (PPV) was 88.5%, and the negative predictive value (NPV) was 94.4%. The likelihood ratios (LR+) and (LR−) were 13.8 and 0.12, respectively. Radiologists had a slightly higher sensitivity (91.1%) and specificity (92.0%) than ED physicians, whose sensitivity was 88.9% and specificity was 93.9%. Advanced ED sonographers had the highest conclusive rate (75.0%) and diagnostic accuracy, while inexperienced ED sonographers had lower sensitivity (87.5%) and specificity (91.5%), with a higher percentage of inconclusive scans (37.5%).

Table 2: Overview of Diagnostic Characteristics of All Conclusive Sonographies:

Group	**N total**	**N conclusive (% of total)**	**Sensitivity (95% CI)**	**Specificity (95% CI)**	***PPV (95% CI)****	***NPV (95% CI)****	**LR+ (95% CI)**	**LR− (95% CI)**	**N inconclusive (% of total)**

Overall	258	180 (69.8%)	89.6% (82.1 to 94.3)	93.5% (88.2 to 97.0)	88.5% (81.1 to 93.2)	94.4% (90.0 to 97.2)	13.8 (7.4 to 25.2)	0.12 (0.07 to 0.19)	78 (30.2%)
Radiologists	90	65 (72.2%)	91.1% (82.0 to 97.1)	92.0% (84.5 to 96.7)	87.7% (77.5 to 94.2)	93.6% (85.4 to 97.8)	11.4 (4.6 to 28.0)	0.10 (0.03 to 0.32)	25 (27.8%)
ED Physicians overall	168	115 (68.5%)	88.9% (80.2 to 94.7)	93.9% (87.5 to 97.5)	89.9% (81.4 to 95.2)	93.5% (87.9 to 97.1)	15.3 (7.8 to 30.1)	0.11 (0.05 to 0.24)	53 (31.5%)
Advanced ED Sonographers	80	60 (75.0%)	90.5% (78.2 to 97.3)	94.7% (86.7 to 98.3)	90.2% (77.8 to 96.1)	95.0% (88.6 to 98.3)	17.1 (6.8 to 43.2)	0.09 (0.03 to 0.25)	20 (25.0%)
Inexperienced ED Sonographers	88	55 (62.5%)	87.5% (72.6 to 96.2)	91.5% (80.0 to 97.9)	85.5% (70.1 to 94.6)	92.8% (82.0 to 97.7)	10.3 (3.1 to 34.0)	0.13 (0.04 to 0.45)	33 (37.5%)

Discussion

This study demonstrates that a pragmatic, ultrasound-based approach to diagnosing acute appendicitis in adult patients in the emergency department (ED) is both feasible and highly effective. The diagnostic accuracy metrics, particularly the sensitivity (89.6%) and specificity (93.5%) observed in this study, align with previous research on the use of ultrasound for appendicitis, reinforcing its utility as a reliable imaging tool. The positive predictive value (PPV) of 88.5% and negative predictive value (NPV) of 94.4% suggest that ultrasound can substantially reduce diagnostic uncertainty, guiding clinical decisions and improving patient outcomes[10]. While computed tomography (CT) remains the gold standard for diagnosing appendicitis due to its high sensitivity and specificity, ultrasound offers several key advantages. Ultrasound is non-invasive, radiation-free, and readily available in most EDs, making it a particularly attractive option for younger patients or those where radiation exposure is a concern[11]. In this study, ultrasound was highly accurate in detecting appendicitis, especially when performed by radiologists and advanced ED sonographers. The sensitivity of 91.1% among radiologists and 90.5% among advanced ED sonographers indicates that, with proper training and experience, ultrasound can approach the diagnostic performance of CT, making it a viable first-line imaging modality. One of the main limitations of ultrasound is its operator dependence[12]. The results in this study clearly highlight the impact of operator experience on diagnostic accuracy. Advanced ED sonographers achieved significantly higher sensitivity (90.5%) and specificity (94.7%) compared to less experienced sonographers (87.5% and

91.5%, respectively). This finding underscores the importance of adequate training and experience when performing ultrasound for appendicitis. In settings where experienced sonographers are available, ultrasound can be highly reliable; however, in hospitals with less experienced staff, additional training may be required to maximize the accuracy of this diagnostic tool[13]. A notable limitation was the number of inconclusive ultrasound results (30.2%). These cases often required additional imaging, such as CT, to confirm or rule out appendicitis. Most inconclusive cases were attributed to technical challenges, such as poor visualization of the appendix due to patient obesity or bowel gas. While ultrasound provides a high level of accuracy when the appendix is visualized, its limitations in certain patient populations highlight the need for complementary imaging techniques[14]. Future studies may explore ways to reduce inconclusive results, perhaps through advancements in ultrasound technology or by improving protocols to enhance visualization in difficult cases. The high diagnostic accuracy achieved in this study suggests that ultrasound can be effectively integrated into ED protocols for evaluating patients with suspected appendicitis. Ultrasound's ability to provide rapid, bedside assessments can help streamline patient management, allowing for quicker decision-making regarding surgical intervention or further imaging. Additionally, using ultrasound as a first-line diagnostic tool has the potential to reduce healthcare costs by minimizing the need for CT scans and avoiding unnecessary surgeries in patients without appendicitis[15].

The low negative likelihood ratio ($LR- = 0.12$) suggests that a negative ultrasound result strongly reduces the probability of appendicitis, allowing clinicians to confidently rule out the diagnosis in many cases[16]. Similarly, the high positive likelihood ratio ($LR+ = 13.8$) indicates that a positive ultrasound finding significantly increases the likelihood of appendicitis, supporting prompt surgical referral when appropriate.

Limitations and Future Research

Despite its strengths, this study has several limitations. First, the study was conducted in a single center, which may limit the generalizability of the findings to other hospitals with different levels of ultrasound expertise. Second, although ultrasound was highly effective in diagnosing appendicitis, a significant proportion of cases were inconclusive, particularly among inexperienced sonographers and obese patients. Future studies should investigate

methods to improve visualization and reduce inconclusive cases, potentially through enhanced imaging techniques or better protocols for difficult patients.

Conclusion

It is concluded that a pragmatic, ultrasound-based approach is an effective and reliable tool for diagnosing acute appendicitis in adult patients in the emergency department. The high sensitivity, specificity, and predictive values achieved in this study support its use as a first-line imaging modality, particularly when performed by experienced operators. While challenges remain in certain cases, such as in obese patients, ultrasound significantly reduces the need for further imaging and unnecessary surgeries, improving patient care and resource utilization.

References

1. Hastings, R.S. & Powers, R.D., 2011. Abdominal pain in the ED: a 35-year retrospective. *American Journal of Emergency Medicine*, 29(6), pp.711–716. doi:10.1016/j.ajem.2010.01.045. Available at: http://www.ncbi.nlm.nih.gov/pubmed/20825873.
2. Strömberg, C., Johansson, G. & Adolfsson, A., 2007. Acute abdominal pain: diagnostic impact of immediate CT scanning. *World Journal of Surgery*, 31(11), pp.2347–2354. doi:10.1007/s00268-007-9233-x. Available at: http://www.ncbi.nlm.nih.gov/pubmed/17896131.
3. Öztürk, A., Korkmaz, M., Atalay, T. & et al., 2017. The role of doctors and patients in appendicitis perforation. *American Surgeon*, 83(4), pp.390–393. doi:10.1177/000313481708300428. Available at: http://www.ncbi.nlm.nih.gov/pubmed/28424136.
4. Wen, S.W. & Naylor, C.D., 1995. Diagnostic accuracy and short-term surgical outcomes in cases of suspected acute appendicitis. *CMAJ*, 152(10), pp.1617–1626. Available at: http://www.ncbi.nlm.nih.gov/pubmed/7743448.
5. Al-Omran, M., Mamdani, M. & McLeod, R.S., 2003. Epidemiologic features of acute appendicitis in Ontario, Canada. *Canadian Journal of Surgery*, 46(4), pp.263–268. Available at: http://www.ncbi.nlm.nih.gov/pubmed/12930102.
6. Sammalkorpi, H.E., Mentula, P., Savolainen, H. & et al., 2017. The introduction of adult appendicitis score reduced negative appendectomy rate. *Scandinavian Journal of Surgery*, 106(3), pp.196–201. doi:10.1177/1457496916683099. Available at: http://www.ncbi.nlm.nih.gov/pubmed/28737110.
7. Corson-Knowles, D. & Russell, F.M., 2018. Clinical ultrasound is safe and highly specific for acute appendicitis in moderate to high pre-test probability patients. *Western Journal of Emergency Medicine*, 19(3), pp.460–464. doi:10.5811/westjem.2018.1.36891. Available at: http://www.ncbi.nlm.nih.gov/pubmed/29760840.

8. Matthew Fields, J., Davis, J., Alsup, C. & et al., 2017. Accuracy of point-of-care ultrasonography for diagnosing acute appendicitis: a systematic review and meta-analysis. *Academic Emergency Medicine*, 24(9), pp.1124–1136. doi:10.1111/acem.13212. Available at: http://www.ncbi.nlm.nih.gov/pubmed/28464459.
9. Lee, S.H. & Yun, S.J., 2019. Diagnostic performance of emergency physician-performed point-of-care ultrasonography for acute appendicitis: a meta-analysis. *American Journal of Emergency Medicine*, 37(4), pp.696–705. doi:10.1016/j.ajem.2018.07.025. Available at: http://www.ncbi.nlm.nih.gov/pubmed/30017693.
10. Keller, C., Wang, N.E., Imler, D.L. & et al., 2017. Predictors of nondiagnostic ultrasound for appendicitis. *Journal of Emergency Medicine*, 52(3), pp.318–323. doi:10.1016/j.jemermed.2016.07.101. Available at: http://www.ncbi.nlm.nih.gov/pubmed/27692650.
11. Pelin, M., Paquette, B., Revel, L. & et al., 2018. Acute appendicitis: factors associated with inconclusive ultrasound study and the need for additional computed tomography. *Diagnostic and Interventional Imaging*, 99(11), pp.809–814. doi:10.1016/j.diii.2018.07.004. Available at: http://www.ncbi.nlm.nih.gov/pubmed/30197245.
12. Snyder, M.J., Guthrie, M. & Cagle, S., 2018. Acute appendicitis: efficient diagnosis and management. *American Family Physician*, 98(1), pp.25–33.
13. Gregory, S., Kuntz, K., Sainfort, F. & Kharbanda, A., 2016. Cost-effectiveness of integrating a clinical decision rule and staged imaging protocol for diagnosis of appendicitis. *Value in Health*, 19(1), pp.28–35. doi:10.1016/j.jval.2015.10.007.
14. Andersson, M. & Andersson, R.E., 2008. The appendicitis inflammatory response score: a tool for the diagnosis of acute appendicitis that outperforms the Alvarado score. *World Journal of Surgery*, 32, pp.1843–1849. doi:10.1007/s00268-008-9649-y.
15. Sammalkorpi, H.E., Mentula, P. & Leppäniemi, A., 2014. A new adult appendicitis score improves diagnostic accuracy of acute appendicitis-a prospective study. *BMC Gastroenterology*, 14(1), p.114. doi:10.1186/1471-230X-14-114.
16. Sippola, S., Virtanen, J., Tammilehto, V., Grönroos, J., Hurme, S., Niiniviita, H., Lietzen, E. & Salminen, P., 2020. The accuracy of low-dose computed tomography protocol in patients with suspected acute appendicitis: the OPTICAP study. *Annals of Surgery*, 271(2), pp.332–338. doi:10.1097/SLA.0000000000002976.